Claims

What is claimed is:

1. An apparatus for formation of a three dimensional object comprising:

a sealed container;

an electron beam subsystem capable of directing energy within said container;

a positioning subsystem contained within said container;

a wire feed subsystem contained within said container;

an instrumentation subsystem electronically connected to said electron beam subsystem, positioning subsystem, and wire feed subsystem; and

a power distribution subsystem electrically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, and said instrumentation subsystem.

2. The apparatus of Claim 1, further comprising a substrate attached to said positioning subsystem.

3. The apparatus of Claim 1, further comprising a rack housing said sealed container, instrumentation subsystem, power distribution subsystem, or any combination.

4. An apparatus for formation of a three dimensional object by a sequential deposition of a wire feedstock comprising:

a sealed container capable of maintaining a vacuum environment;

a positioning subsystem contained within said container and capable of controlling the position of said object;

a wire feed subsystem contained within said container and capable of depositing said wire feedstock relative to said position of said object;

an electron beam subsystem capable of directing energy within said container and directing energy relative to said position of said object;

a vacuum subsystem capable of creating and sustaining said vacuum environment in said container;

an instrumentation subsystem electronically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, and vacuum subsystem; and

a power distribution subsystem electrically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, vacuum subsystem, and said instrumentation subsystem.

5. The apparatus of Claim 4, further comprising a substrate attached to said positioning subsystem wherein said sequential deposition of said wire feedstock is initiated on said substrate.

6. The apparatus of Claim 4, wherein said container is comprised of:

a frame; and

at least one wall attached to said frame.

7. The apparatus of Claim 6, wherein said frame and at least one wall is formed of a material selected from a group consisting of metal, metal alloy, ceramic, ceramic composite, metal matrix composite, and polymer matrix composite.

8. The apparatus of Claim 6, wherein said frame and at least one wall is formed of a material selected from the group consisting of titanium, aluminum, aluminum alloys, beryllium alloys and stainless steel.

9. The apparatus of Claim 6, wherein said container is further comprised of rack-mounting hardware attached to said at least one wall, said frame, or both.

10. The apparatus of Claim 6, wherein said container is further comprised of a descendible base attached to said frame.

11. The apparatus of Claim 6, where said container is further comprised of:

at least one window attached to said at least one wall;

at least one door attached to said frame, to said wall, or both;

at least one electrical feed-through attached to said at least one wall; and

at least one plumbing feed-through attached to said at least one wall.

12. The apparatus of Claim 11, wherein said window is formed of a transparent material.

13. The apparatus of Claim 11, wherein said at least one door is formed of a material selected from a group consisting of metal, metal alloy, ceramic, and ceramic composite.

14. The apparatus of Claim 4, wherein said container has a rectilinear, ellipsoidal, or arbitrary cross-sectional shape.

15. The apparatus of Claim 4, wherein said electron beam subsystem is comprised of:

an electron beam gun capable of directing said energy wherein said electron beam gun incorporates at least one focusing coil and at least one deflection coil;

an electron beam control element capable of controlling the delivery of said energy from said electron beam gun and electronically connected to said instrumentation subsystem and said electron beam gun; and

an electron beam power subsystem electrically connected to said electron beam gun and said electron beam control element and wherein said electron beam power subsystem is capable of supplying power to said electron beam gun and said electron beam control element.

16. The apparatus of Claim 4, wherein said electron beam subsystem is comprised of:

an electron beam gun capable of directing said energy;

an electron beam control element capable of controlling the delivery of said energy from said electron beam gun and electronically connected to said instrumentation subsystem and said electron beam gun;

at least one focusing coil contained within said electron beam gun and capable of focusing said energy;

at least one deflection coil contained within said electron beam gun and capable of deflecting said energy; and

an electron beam power subsystem electrically connected to said power distribution subsystem, said electron beam gun, said electron beam control element, said at least one focusing coil, and said at least one deflection coil.

17. The apparatus of Claim 16, wherein said electron beam control element is comprised of at least one electron beam sensor electronically connected to said electron beam gun and said instrumentation subsystem and wherein said electron beam sensor is electrically connected to said power distribution subsystem.

18. The apparatus of Claim 17, wherein said electron beam control element is further comprised of at least one electron beam microprocessor electronically connected to said at least one electron beam sensor and said instrumentation subsystem and wherein said microprocessor is electrically connected to said power distribution subsystem.

19. The apparatus of Claim 16, wherein said electron beam subsystem is further comprised of:

at least one auxiliary vacuum pump connected to said electron beam gun, electrically connected to said power distribution subsystem, and capable of creating and sustaining a vacuum level within said electron beam gun;

at least one service panel attached to said electron beam gun and electrically connected to said power distribution subsystem; and

at least one user interface screen electronically connected to said electron beam control element and electrically connected to said power distribution subsystem.

20. The apparatus of Claim 16, wherein said electron beam subsystem is further comprised of an electron beam positioning subsystem capable of positioning said electron beam gun relative to

said position of said object wherein said electron beam positioning subsystem is electronically connected to said electron beam control element and electrically connected to said power distribution subsystem.

21. The apparatus of Claim 16, wherein said electron beam subsystem is further comprised of an electron beam positioning subsystem capable of positioning said electron beam gun relative to said position of said object wherein said electron beam positioning subsystem is electronically connected to said instrumentation subsystem and electrically connected to said power distribution subsystem.

22. The apparatus of Claim 20, wherein said electron beam positioning subsystem is comprised of:

at least one electron beam gun positioning motor mechanically attached to said electron beam gun and electrically connected to said power distribution subsystem;

at least one electron beam positioning subsystem sensor electronically connected to said electron beam gun positioning motor and said electron beam control element, and wherein said electron beam positioning subsystem sensor is electrically connected to said power distribution subsystem; and

at least one conductor capable of supplying power to said at least one electron beam gun positioning motor and electrically connected to said at least one electron beam gun positioning motor and to said power distribution subsystem.

23. The apparatus of Claim 16, wherein said electron beam subsystem operates from input power in a voltage range from about 100V to about 240V.

24. The apparatus of Claim 23, wherein said electron beam subsystem operates from input power of about 110V.

25. The apparatus of Claim 16, wherein said electron beam gun is partially contained inside said container.

26. The apparatus of Claim 16, wherein said electron beam gun has an accelerating voltage up to about 60kV.

27. The apparatus of Claim 26, wherein said electron beam gun has an accelerating voltage up to about 15kV.

28. The apparatus of Claim 16, wherein said electron beam gun has a beam power from about 3kW to about 10kW.

29. The apparatus of Claim 28, wherein said electron beam gun has a beam power from about 3kW to about 5kW.

30. The apparatus of Claim 4, wherein said positioning subsystem is comprised of:

a moveable platform contained within said container;

at least one positioning subsystem motor capable of moving said moveable platform and electrically connected to said power distribution subsystem; and

a positioning subsystem control element capable of controlling said position of said object, wherein said positioning subsystem control element is electronically connected to said instrumentation subsystem, said moveable platform, and said at least one positioning subsystem motor, and wherein said positioning subsystem control element is electrically connected to said power distribution subsystem.

31. The apparatus of Claim 30, wherein said positioning subsystem is further comprised of:

a means for providing electrical continuity electrically connected to said positioning subsystem control element and said at least one positioning subsystem motor;

a means for providing thermal and electrical isolation attached to said positioning subsystem control element, said at least one positioning subsystem motor, and said means for providing electrical continuity;

a means for providing protective shielding attached to said moveable platform; and

a means for clamping attached to said moveable platform.

32. The apparatus of Claim 30, wherein said moveable platform is a four axes moveable platform.

33. The apparatus of Claim 32, wherein said four axes moveable platform has an accuracy of +/- 0.001 for each linear axis of X, Y, and Z and 0.01 degrees for the a-axis of rotation in the X-Y plane.

34. The apparatus of Claim 32, wherein said four axes moveable platform has a translational speed up to about 250 inches per minute for each linear axis of X, Y, and Z and a rotational speed up to about 20 rotations per minute for the a-axis of rotation in the X-Y plane.

35. The apparatus of Claim 34, wherein said four axes moveable platform has a translational speed up to about 50 inches per minute for each linear axis of X, Y, and Z and a rotational speed up to about 10 rotations per minute for the a-axis of rotation in the X-Y plane.

36. The apparatus of Claim 30, wherein said moveable platform is a five axes moveable platform.

37. The apparatus of Claim 4, wherein said wire feed subsystem is comprised of:

said wire feedstock;

a wire feed housing contained within said container and capable of accommodating said wire feedstock;

at least one wire feed motor attached to said wire feed housing and electrically connected to said power distribution subsystem;

a wire feeding mechanism attached to said wire feed housing, mechanically connected to said wire feed motor, and wherein said wire feedstock is threaded through said wire feeding mechanism;

at least one wire feed nozzle attached to said wire feed housing and wherein said wire feedstock is fed through said wire feed nozzle; and

a wire feed control element electronically connected to said instrumentation subsystem, said wire feed motor, said wire feeding mechanism, and said at least one wire feed nozzle and electrically connected to said power distribution subsystem.

38. The apparatus of Claim 37, wherein said wire feed subsystem is further comprised of a wire feed positioning subsystem electrically connected to said power distribution subsystem, electronically connected to said wire feed control element, and capable of positioning said at least one wire feed nozzle relative to said position of said object.

39. The apparatus of Claim 37, wherein said wire feedstock has an ellipsoidal cross-sectional shape.

40. The apparatus of Claim 37, wherein said wire feedstock is formed of a material selected from a group consisting of metal and metal alloy.

41. The apparatus of Claim 37, wherein said wire feed control element is comprised of at least one wire feed sensor attached to said wire feed housing; electronically connected to said instrumentation subsystem, said wire feed motor, said wire feeding mechanism, and said at least one wire feed nozzle; and electrically connected to said power distribution subsystem

42. The apparatus of Claim 41, wherein said wire feed control element is further comprised of at least one wire feed microprocessor electronically connected to said instrumentation

subsystem and said at least one wire feed sensor, and electrically connected to said power distribution subsystem.

43. The apparatus of Claim 4, wherein said vacuum subsystem creates and sustains a pressure from about 10^{-4} torr to about 10^{-6} torr in said container.

44. The apparatus of Claim 4, wherein said vacuum subsystem is comprised of:

a plumbing subsystem connected to said container;

at least one pump connected to said plumbing subsystem and capable of creating and sustaining said vacuum environment in said container; and

a vacuum control element electrically connected to said power distribution subsystem, electronically connected to said instrumentation subsystem, and capable of controlling said at least one pump and said plumbing subsystem.

45. The apparatus of Claim 44, wherein said plumbing subsystem is comprised of:

at least one connecting device connected to said container; and

at least one duct connected to said at least one connecting device.

46. The apparatus of Claim 45, wherein said plumbing subsystem is further comprised of:

at least one valve connected to said at least one duct, said at least one connecting device, or both;

at least one flange connected to said at least one duct, said at least one connecting device, said at least one valve, or any combination;

at least one filter connected to said at least one duct; and

at least one shock suppression component attached to said at least one pump.

47. The apparatus of Claim 44, wherein said at least one pump is selected from a group consisting of a turbomolecular pump, a scroll pump, an ion pump, a roughing pump, a cryopump, and a diffusion pump.

48. The apparatus of Claim 44, wherein said vacuum control element is comprised of at least one vacuum subsystem sensor electronically connected to said instrumentation subsystem, said at least one pump, and said plumbing subsystem.

49. The apparatus of Claim 4, wherein said instrumentation subsystem is comprised of:

a means for commanding and controlling data electrically connected to said power distribution subsystem and electronically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, and vacuum subsystem;

a means for measuring processing conditions electronically connected to said means for commanding and controlling data; and

a means for recording data electronically connected to said means for commanding and controlling data.

50. The apparatus of Claim 49, wherein said instrumentation subsystem is further comprised of:

a visual monitoring means for monitoring the fabrication process electronically connected to the means for commanding and controlling data;

a means for monitoring a predetermined set of parameters related to the fabrication process electronically connected to the means for commanding and controlling data; and

a means for lighting electronically connected to said visual monitoring means for monitoring the fabrication process.

51. The apparatus of Claim 49, wherein said instrumentation subsystem is further comprised of at least one camera electrically connected to said power distribution subsystem.

52. The apparatus of Claim 51, wherein said camera is selected from a group consisting of a motion video camera, a still image camera, and a thermal image camera.

53. The apparatus of Claim 4, wherein said power distribution subsystem is comprised of:

a means for providing an electrical connection electrically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, vacuum subsystem, and said instrumentation subsystem;

a means for conditioning power electrically connected to said means for providing an electrical connection;

a means for apportioning power electrically connected to said means for providing an electrical connection;

a means for distributing power electrically connected to said means for providing an electrical connection; and

a means for protecting system components from electrical hazards electrically connected to said means for providing an electrical connection.

54. The apparatus of Claim 53, wherein said power distribution subsystem further comprises:

an uninterruptible power source electrically connected to said means for providing an electrical connection; and

a main shutoff switch electrically connected to said means for providing an electrical connection.

55. The apparatus of Claim 53, wherein said power distribution subsystem further comprises a means for managing power electrically connected to said means for electrical connection.

56. An apparatus for formation of a three dimensional object by a sequential deposition of a wire feedstock comprising:

a sealed container capable of maintaining a vacuum environment;

a positioning subsystem contained within said container and capable of controlling the position of said object;

an electron beam subsystem capable of directing energy within said container and directing energy relative to said position of said object;

a wire feed subsystem contained within said electron beam subsystem and capable of depositing said wire feedstock relative to said position of said object;

a vacuum subsystem connected to said container and capable of creating and sustaining said vacuum environment in said container;

an instrumentation subsystem electronically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, and vacuum subsystem; and

a power distribution subsystem electrically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, vacuum subsystem, and said instrumentation subsystem.

57. An apparatus for formation of a freeform three dimensional object comprising:

a containment means for enclosing a workspace;

a delivery means contained within said containment means and for depositing a feedstock material in a predetermined pattern and a predetermined rate onto a target;

a positioning means contained within said containment means and for positioning said target to a predetermined location;

an electron beam subsystem capable of directing energy within said container and directing energy relative to said target;

an atmospheric pressure control means connected to said containment means and for creating and maintaining a vacuum environment inside said containment means;

a command, control, and communications means electronically connected to said containment means, electronically connected to said delivery means, electronically connected to said heating means, electronically connected to said positioning means, electronically connected to said atmospheric control means, and for commanding, controlling, and providing communications for said delivery means, said heating means, said positioning means, and said atmospheric pressure control means; and

a power distribution means electrically connected to said delivery mean, said heating means, said positioning means, said atmospheric control means, and said command, control, and communications means and for distributing power to said delivery means, said positioning means, said heating means, said atmospheric pressure control means, and said command, control, and communications means.

58. An apparatus for formation of a three dimensional object in interplanetary space by a sequential deposition of a wire feedstock comprising:

a frame;

a positioning subsystem attached to said frame and capable of controlling the position of said object;

a wire feed subsystem attached to said frame and capable of depositing said wire feedstock relative to said position of said object;

an electron beam subsystem capable of directing energy relative to said position of said object;

an instrumentation subsystem electronically connected to said electron beam subsystem, positioning subsystem, and wire feed subsystem; and

a power distribution subsystem electrically connected to said electron beam subsystem, positioning subsystem, wire feed subsystem, and said instrumentation subsystem.

59. A method for fabricating a three dimensional object from a wire material in a solid freeform fabrication apparatus comprising a sealed container, an electron beam gun, a positioning element, and a wire feed subsystem said method comprising the steps of:

affixing a substrate material to said positioning element;

de-pressurizing said sealed container to a predetermined pressure;

positioning said substrate by moving said positioning subsystem to a predetermined location relative to said substrate and said wire feed subsystem;

heating said substrate with said electron beam gun to create and sustain a molten pool;

depositing said wire material on said substrate and into said molten pool in layers from said wire feed subsystem; and

building successive layers on said substrate by repeating said positioning, heating, and depositing steps.